

National Aeronautics and  
Space Administration

**Lyndon B. Johnson Space Center**  
2101 NASA Parkway  
Houston, Texas 77058-3696



June 6, 2010

Reply to Attn of: EA3-10-019

To: Air Force Global Logistics Support Center 401 (AFGLSC 401)  
Supply Chain Management Squadron/ (SCMS/GUMAA), Wright-Patterson Air  
Force Base (WPAFB)

Subject: REQUEST for WAIVER for Section A.3.9.3 Magnetized Material of  
AFMAN24-204

Later this year, the Alpha Magnetic Spectrometer 02 (AMS-02)- which is a Department of Energy (DOE) sponsored particle physics detector – is destined to fly on the International Space Station (ISS). The Space Shuttle will transport the AMS-02 in the cargo bay to install it on the International Space Station S3 (ISS S3).

The enclosure provides details of the Waiver for Section A.3.9.3 Magnetized Material of AFMAN24-204 with regard to the AMS-02.

Sincerely,

A handwritten signature in black ink, appearing to read "Trent D. Martin", with a long horizontal line extending to the right.

Trent D. Martin  
NASA AMS Project Manager

Enclosures



June 6, 2010

Dear Sirs,

The Alpha Magnetic Spectrometer 02 (AMS-02) is a Department of Energy (DOE)-sponsored particle physics detector destined to fly on the International Space Station (ISS) later this year. The assembly and testing of the experiment has been completed in Europe, and it is soon to be ready for transport to Kennedy Space Center (KSC), co-located with Cape Canaveral Air Force Station, Florida. The AMS-02 will be transported in the cargo bay of the Space Shuttle for installation on the International Space Station S3 (ISS S3). Once on the ISS Upper Inboard Payload Attach Site, the AMS-02 will remain active for at least ten years.



**Figure 1. AMS-02 on S3 Truss of ISS.**

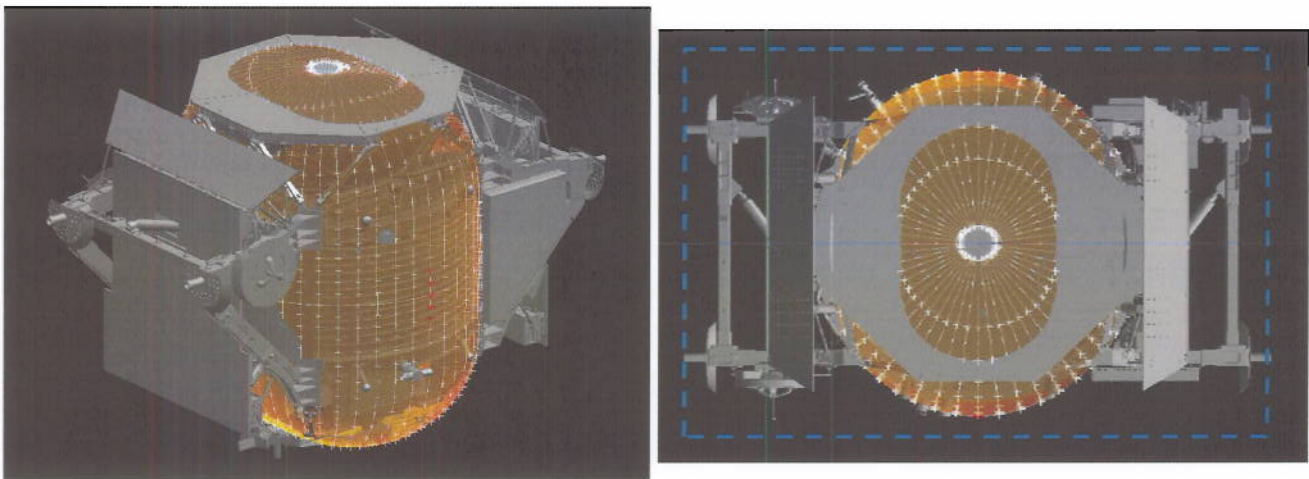
Orbiting the Earth at an altitude of 200 nautical miles, the AMS-02 is pioneering a new frontier in particle physics research for the 21st century. This unique scientific mission of exploration seeks to understand fundamental issues shared by physics, astrophysics, and cosmology on the origin and structure of the Universe. Although the AMS-02 is specifically looking for anti-matter and dark matter, as the first magnetic spectrometer in space, AMS-02 has and will collect information from cosmic sources emanating from stars and galaxies millions of light years beyond the Milky Way. The technical challenges to build such a detector for use in space have been surmounted through the close collaboration of the AMS-02 scientists and industries around the world whose efforts have resulted in the development of new technologies and higher standards of precision.

The experiment utilizes a large, permanent magnet assembly to produce a uniform magnetic field ( $\sim 0.16$  Tesla) over a large volume of  $\sim 1\text{m}^3$ . The magnetic field is used to bend the path of charged cosmic particles as they pass through five different types of detectors. The permanent magnet is constructed in a dipole arrangement

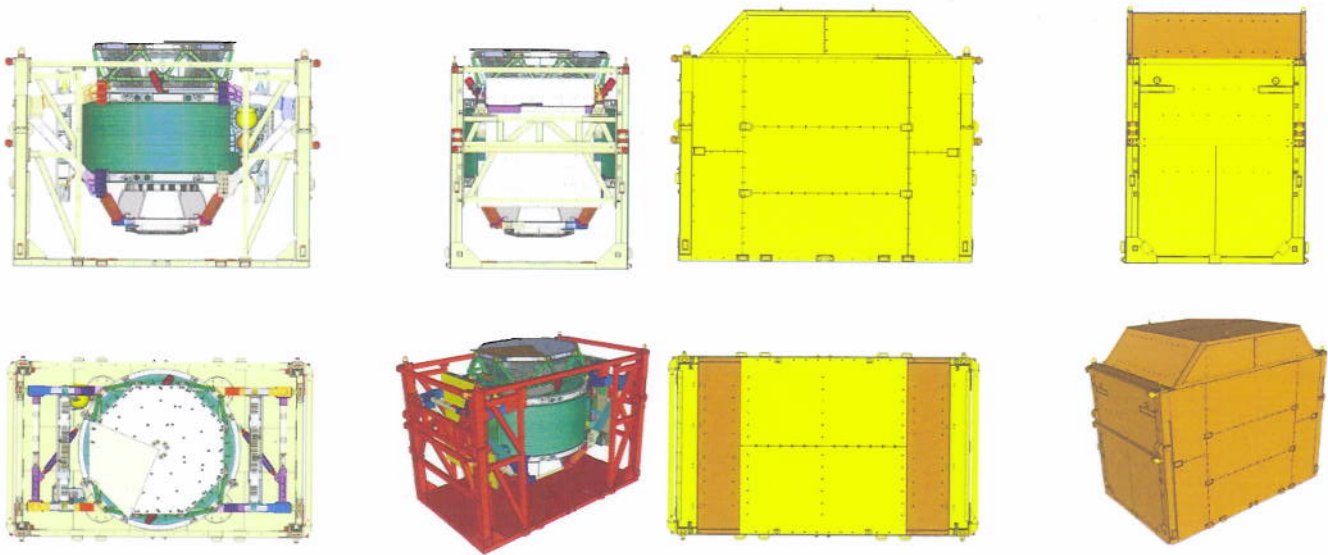
specifically designed to minimize the effects of its external magnetic field on the ISS S3 and the surroundings. The single magnet assembly is centered inside the experiment and the shipping container.



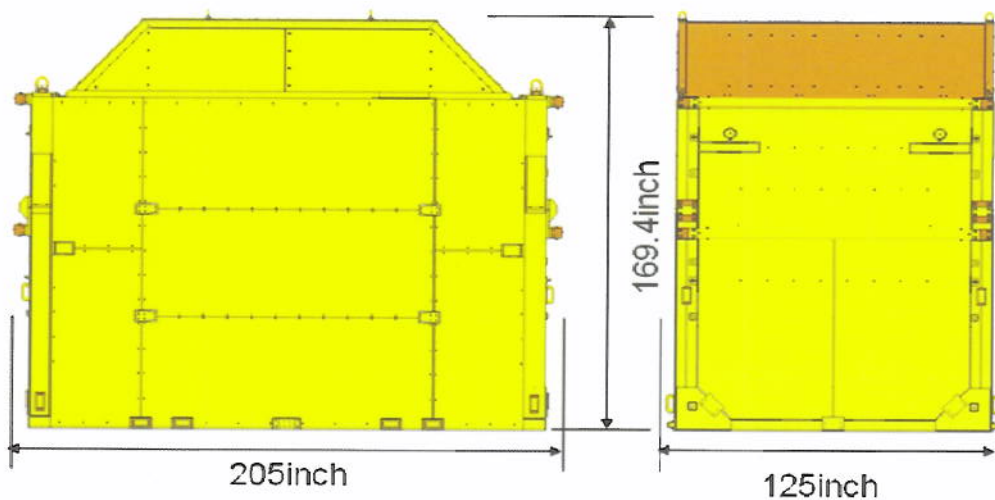
**Figure 2. AMS-02 in the Primary Support Stand (PSS) shipping fixture without covers installed. TheMagnet is inside the white cylinder.**



**Figure 3. AMS-02 Magnetic Field maps (10 Gauss surface) inside the PSS envelope (blue line), by analysis.**



**Figure 4. AMS-02 in the PSS Shipping Container with and without covers.**



**Figure 5. Overall dimensions of AMS-02 in the PSS Shipping Container with covers.**

The magnet is Class 9 material consistent with Sections A3.3.9.3 and A3.11 Magnetized Material of Air Force Manual 24-204 (AFMAN24-204). The AMS-02 Collaboration is requesting a waiver for these sections of AFMAN24-204. The reasons for our request for the waiver are as follows:

#### **Reasons for Request**

1. Due to space constraints associated with building a shielding structure for the field, if we were to build this shield, the AMS-02 payload would not fit in the available height of the C-5A Avionics Modernization Program (AMPed) version of the C-5. Constraints for horizontal loading (no inclined ramp) and the vertical

orientation of the container preclude us from loading from the rear of the plane. This leaves only 4 inches of clearance (without shielding) available inside the C-5A AMPed.

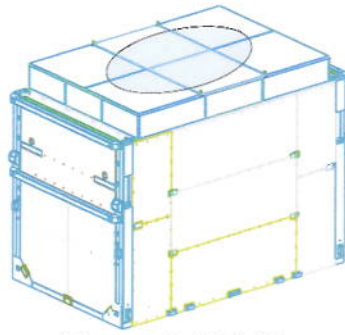
2. The design of the AMS-02 shipping structure, which also serves as the assembly and testing stand for the AMS-02 experiment while being prepared for space flight, does not include the analysis to install the additional weight that magnetic shielding would require. Current estimates put that weight at up to 3900 pounds.
3. Preliminary analysis shows that the shipping structure would not be able to accept the additional weight of the shielding material.

**Mitigating factors affecting this regulation are as follows.**

1. The magnetic field of AMS-02 is a Direct Current (DC) (steady) field, therefore, it does not interfere with electronics, cabling, and avionics in the same manner an Alternating Current (AC) (alternating) magnetic field would.
2. The external field of our shipping container, while not meeting the requirement, does decay quickly to near background levels (Earth's field is 0.5 Gauss) within 15 feet of the AMS-02 shipping container. The values are well below the 0.5 Gauss of the Earth's magnetic field. The highest AMS-02 field strength, as shown below in section 2.2 (0.108 Gauss), is only 22% of the Earth's field of 0.5 Gauss at 15 feet.
  - 2.1. We will have a steel plate under the Payload, so in the -Z direction, the field will be attenuated to less than 1 Gauss around the bottom surface of the shipping container and less than 0.3 Gauss at 1 meter (40 inches) below the payload.
  - 2.2. For the remaining directions, the table below gives the Gauss levels at 15 feet from the surfaces of the container; the field is symmetric in X, -X and Y, -Y.

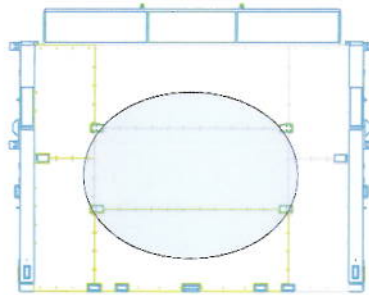
+/- X (ft)	+/- Y (ft)	+Z (ft)	B (Gauss)
15	0	0	(+/-)0.108
0	15	0	(+/-)0.037
0	0	15	(+)0.068

The long (Y) axis of our shipping container is oriented with the body of the C-5A AMPed. The X axis is facing the wings.



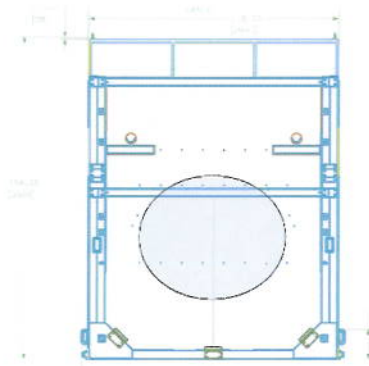
**Figure 6. Z Field.**

For the top (Z) surface of our shipping container, there is a max of 4.4 Gauss in a small area at the geometric center of the top (~ 2 square meters). Three feet from the surface of our shipping container, there is a max of 0.8 Gauss in a small area at the geometric center of the top.



**Figure 7. X Field.**

For the X surface of our shipping container, there is a max of 12 Gauss in a small area at the geometric center of the both sides (~ 2 square meters). Three feet from the surface of our shipping container, there is a max of 0.5 Gauss in a small area at the geometric center of both sides.



**Figure 8. Y Field.**

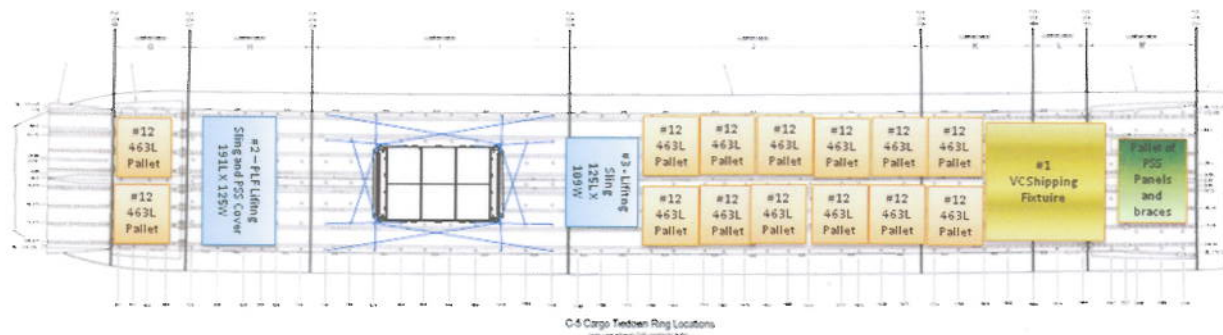
For the Y surface of our shipping container, there is a max of 0.5 Gauss in a small area at the geometric center of both sides (~1 square meter). Three feet from the surface of our shipping container, there is a max of 0.3 Gauss in a small area at the geometric center of both sides

3. The magnetic field in discussion is roughly spherical (see Figure 3 above), therefore, only portions of our container experience higher fields. Locations for sling and chain attachments are not in a higher field area. The C-5A AMPed does not use magnetic compasses for its guidance and control system; therefore, the guidance system is not affected by our field. (See Reference 1.)
4. We have been issued concurrence from 730 Air Cargo Services Group (ACSG/CC), C-5 Engineering System Program Office (SPO) at Warner Robins – Air Logistics Center (WR-ALC) via a Safe-To-Fly (STF) recommendation letter verifying that the C-5A AMPed avionics and other aircraft equipment are not affected by magnetic fields. (See Reference 2.)
5. Lockheed Martin Aeronautics (LMA), Original Equipment Manufacturer (OEM) for the C-5, was contacted by the Air Force (AF) to evaluate the shipment of the AMS-02. LMA had two initial concerns as follows:
  - 5.1. First was the potential for induced currents in on-board wiring due to payload vibrations. This was deemed a very small risk by the AF due to the low field strength, distance from the wiring, and current levels in the wiring.
  - 5.2. The second issue was a concern about whether the magnetic field would interfere with landing gear proximity sensors that determined the position of the landing gear. This was investigated by the 730 ACSG/GFEAA, C-5 Engineering SPO at WR-ALC, with some minimal testing in our C-5 lab. Results of this testing was shared with Eldec Corporation, the Original Equipment Manufacturer (OEM) for the landing gear proximity sensors, and Air Force Research Lab where it was agreed that there should be no effect to the landing gear proximity sensors in that this testing subjected the proximity sensors to magnetic fields considerably higher than they will see from the AMS-02 payload.

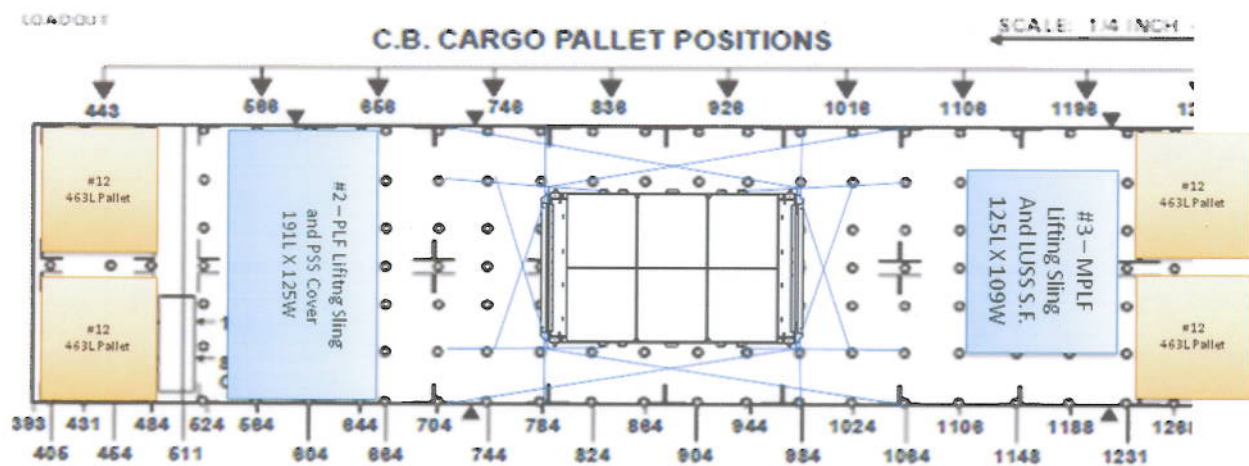
In addition, AMS-02 will ship with a steel plate underneath it attenuating the field below the payload. Also, AMS-02 had a similar issue with a piece of ISS hardware that will move near us while we are deployed on the ISS. It was determined that the magnetic limit sensor in that case was unaffected by similar field strengths.

6. We have a much larger set of hardware than represented in the preliminary load plan. All this extra hardware probably won't meet the maximum weight of the C-5A AMPed, but it could fill all available floor space, meaning, an additional magnetic shielding structure would require us to leave some hardware in Geneva.
7. The payload is shipping from Europe, Geneva, Switzerland, to KSC, Cape Canaveral, Florida. It is impossible for the detector to be adequately protected from corrosion for Transatlantic Ocean ship transport. In addition, schedule constraints remove this option as the additional time would delay our arrival and prevent the scheduled Space Shuttle launch date.
8. We shall comply with all labeling requirements for the magnet.
9. There are no other incompatible materials to be shipped together.

10. For informational purposes, below is a preliminary load plan showing our first desired position in the C-5A AMPed based upon loading / unloading priority. (See Figures 9-12.)

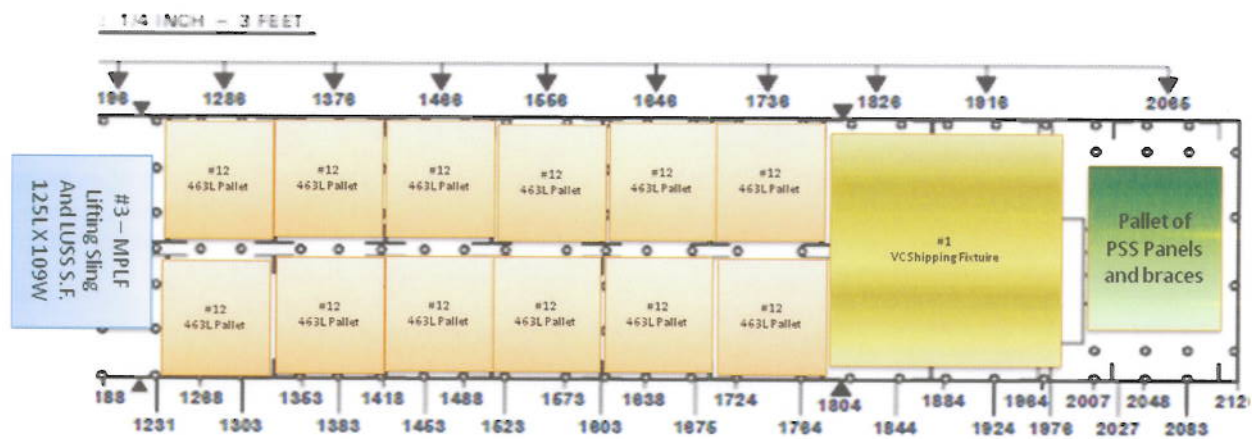


**Figure 9. C-5A Load Plan for AMS-02 Cargo (preliminary).**



Front of C5 showing required space for PSS tiedowns and PLF offloading first.

**Figure 10. Front End of C-5A for AMS-02 Load Plan.**



Rear of C5 showing VC SF loading and maximum 463L usage

Figure 11. Aft End of C-5A for AMS-02 Load Plan.

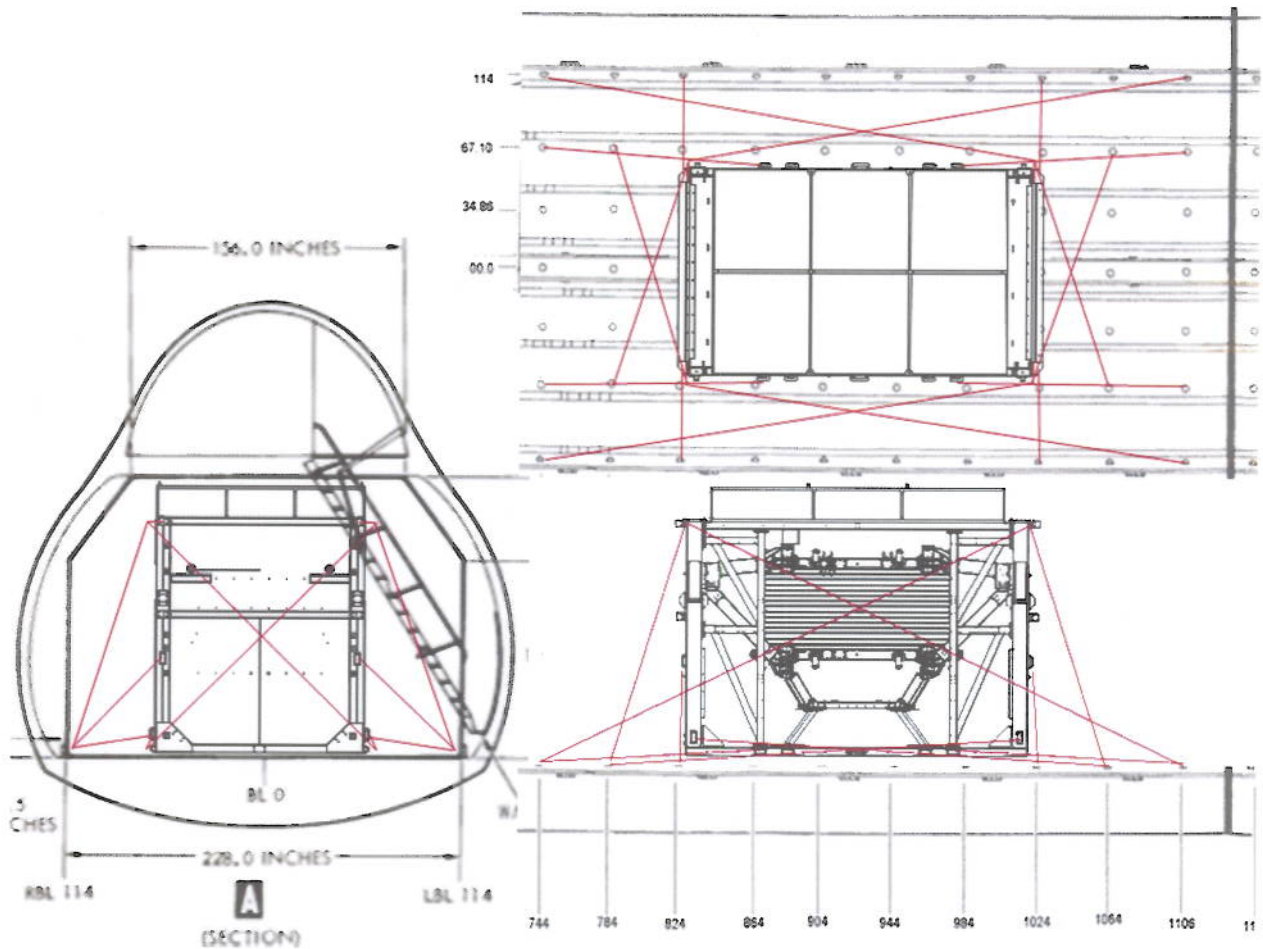


Figure 12. AMS-02 Payload Tie down Scheme. Plan views showing tie down plan. Per Jacobs (ESCG) document ESCG-4450-10-STAN-DOC-0062.



Reference 1

Original Message-----

From: Zentner, John C Ctr USAF AFRL/Ryra [mailto:John.Zentner@WPAFB.AF.MIL]

Sent: Tuesday, June 15, 2010 6:21 AM

To: St. Jean, Dana D. (KSC-UBD00); Martin, Trent D. (JSC-EA321); Heilig, John A; Andersen, John M Civ USAF AFMC ASC/ENFC; Pitman, Nicholas L Civ USAF AFMC 730 ACSG/GFEAA; Combs, Kenneth W YD-02 USAF AFMC 730 ACSG/GFEAA; Tutt, John C; Hoots, Andrew E MSgt USAF AMC AMC/A3VX; McFarland, John E. (KSC-BOE-L100)[BOEING SPACE OPERATIONS COMPANY]; Heimmer, Harold A. (KSC-LXL00)[BOEING SPACE OPERATIONS COMPANY]; Alonso, Jose (KSC-ASRC-407)[ASRC AEROSPACE CORP]

Cc: Delai, Joseph T. (KSC-UBR00)

Subject: RE: C-5 Transportation Magnetic Field Issues

The present C-5A fleet doesn't have a compass system. Many "modern" aircraft do. We at Wright Patterson Air Force Base were surprised to find that the aircraft does not have one. Our navigation people thought that it probably did. However, the primary navigation devices on aircraft are inertial navigation and global positioning systems. The compass system may contribute to the overall navigation solution through a Kalman filtering process which applies weighting to various inputs, but it would not be a big contributor. So even if the aircraft had one, the compass inputs into the navigation system could be turned off without affecting flight safety. Compass systems in the distant past were much bigger players. The only concern with DC magnetic fields has always been the compass system. No electronics have ever been sensitive to the level of magnetic fields we have been discussing. Much stronger fields near certain devices such as cathode ray tube displays and computer hard drives would be a concern.

John Zentner  
AFRL/Ryra, WPAFB, OH  
Comm 937-528-8677, DSN 798-8677

Reference 2

Attached letter from 730 ACSG/CC, WR-ALC

SUBJECT: Safe-To-Fly (STF) Recommendation for the Alpha Magnetic Spectrometer (AMS-02) from Geneva, Switzerland to Kennedy Space Center (KSC), Cape Canaveral, Florida.



**DEPARTMENT OF THE AIR FORCE**  
**730th AIRCRAFT SUSTAINMENT GROUP (AFMC)**  
**ROBINS AIR FORCE BASE, GEORGIA 31098**

MEMORANDUM FOR ASC/ENFC (ATTLA)

FROM: 730 ACSG/CC  
235 Byron Street, Suite 19A  
Robins AFB GA 31098-1670

SUBJECT: Safe-To-Fly (STF) Recommendation for the Alpha Magnetic Spectrometer (AMS-02) from Geneva, Switzerland to Kennedy Space Center (KSC), Cape Canaveral, Florida.

1. Based on the review of the AMS-02 data and information provided by KSC, Jacobs Technology of Houston, TX, Air Force Research Labs (AFRL) at WPAFB, Lockheed Martin Aerospace (LMA) Marietta, GA, 579th Software Maintenance Squadron (579<sup>th</sup> SMXS) at WR-ALC, and Eldec Corporation of Lynwood, WA, it was determined that the AMS-02 will not cause adverse effects on C-5 aircraft navigation or avionics systems and Safe-to-Fly Certification is granted from a technical perspective.
2. A waiver of AFMAN 24-204 regarding the magnetic field strength of the cargo, specifically sections A3.3.9.3 and A13.11, is still required and is the responsibility of the organization wanting to ship the cargo.
3. The points of contact are Nicholas Pitman, 730 ACSG/GFEAA, DSN 468-6859, email [nicholas.pitman@robins.af.mil](mailto:nicholas.pitman@robins.af.mil) and Kenny Combs, 730 ACSG/GFEAA, DSN 427-7946, email [kenny.combs@robins.af.mil](mailto:kenny.combs@robins.af.mil)

A handwritten signature in black ink, appearing to read "R E Alford", is located below the list of points of contact.

RUSSELL E. ALFORD, YF-03, DAF  
Chief Engineer